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TECHNICAL REPORT RR-77-4

SUBMILLIMETER RESEARCH: PRELIMINARY REPORT
ON MILLIMETER AND INFRARED IMAGES OF MILITARY
VEHICLES

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10 November 1976

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The original suggestion to simulate submillimeter images by operating at 940 GHz and scaling the range was made by Dr. J. Allen, Office of Director of Defense for Research and Engineering (DD&E). The selection of target matrix was aided by Dr. V. Corcoran, IDA consultant to DDR&E. Mr. Robert McMillan of Rome Air Development Center gave valuable assistance by smoothing the contractual support. Colonel T. M. Robinson, NGB, USPFO for California, arranged availability of target vehicles. Lieutenant Colonel Reigel, Commander, 3d Battery, 185th Armored Battalion, California National Guard, provided support and allowed the use of facilities and equipment under his command. Dr. N. George, Dr. J. S. Bennett, and Dr. C. R. Christensen have been involved in fruitful discussions of imaging with coherent systems. Collaborators in the US Army Missile Command submillimeter program, Dr. R. L. Hartman and Dr. W. L. Gamble, were involved in this effort from its inception and have provided invaluable advice and support. Most of all, the author thanks Dr. J. M. Baird and Mr. John F. Heney of Hughes Research Laboratory who were truly dedicated to the support of this mission.

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I. INTRODUCTION

This report describes the image data on military vehicles at 3.2 mm and 10.6 ~~mm~~ ^{micrometer} wavelengths obtained by US Army Missile Command (MICOM), Redstone Arsenal, Alabama. The images were obtained through the use of the Hughes Research Laboratory (HRL) mobile images scanning equipment. The data described here were taken during June 7 through 11, 1976 at the California National Guard Armory in San Diego, California. A detailed description of the image scanning equipment and the method used to calibrate the equipment is found in the report entitled Millimeter and Infrared Image Scans of Military Vehicles [1]. An index of the 3.2 mm and 10.6 μ m image data tape is now in preparation [2]. This index will present a brief summary of the equipment and will give calibrated histograms of the images and a sample printout of each image.

II. BACKGROUND

A basic research program was established in December 1975 at MICOM to evaluate the submillimeter wavelength region of the electromagnetic spectrum for possible Army applications. The goal of this program is to determine if an all-weather capability will be provided by utilization of these wavelengths. Initial emphasis was driven by an ASAP summer study in 1974 by Paul W. Kruse which suggested that submillimeter waves could provide sufficient resolution and inclement weather penetration to allow the Army to acquire, recognize, and direct conventional weapons fire onto hostile targets, such as tanks and other military vehicles [3,4,5]. The 1976 ASAP summer study reviewed the MICOM effort [6].

The primary reasons for selecting this wavelength region are as follows:

- 1) Millimeter and centimeter wavelengths are not seriously degraded by inclement weather but they cannot provide sufficient resolution without exceeding the restrictions placed on antenna size by operational systems.
- 2) Optical and infrared wavelengths can provide the required resolution but propagation of these wavelengths in inclement weather is poor.
- 3) Submillimeter wavelengths can be used with system-compatible antenna sizes to provide a narrow beam which will minimize the problem of clutter returns and will provide enough resolution to provide accurate target location, size discrimination, and shape recognition capability. Clear air attenuation is expected to be high, but inclement weather effects should not seriously degrade the beam.

Critical data inadequacies exist in the area of propagation. There is no experimental data on scattering. Measurements of absorption in clear air are limited and do not include detailed meteorological measurements. Observed fluctuations in attenuation are not explained. The theories on clear air absorption do not work well in the atmospheric windows. The data base for extinction in rain, snow, and fog is very limited. A bibliography to provide an introduction to the field of submillimeter propagation is available [7].

Currently, a program is underway at MICOM to obtain a statistically meaningful data base for submillimeter propagation in the atmospheric windows around 0.75, 0.85, and 1.3 mm [8].

It was decided that the most productive technique for evaluating the imaging capability at these wavelengths was not to build an imaging submillimeter radar but rather to use an existing 3.2 mm radar at ranges which simulate the resolution one would obtain with a submillimeter wave radar.

In addition to obtaining the simulated submillimeter data, high resolution images were obtained at 3.2 mm and 10.6 μm . These data are now available in digital format. The high resolution data allow digital image processing to be used to study the effects of image degradation and image enhancement.

The intensity of the returned signal is calibrated with respect to the return from a polished gold sphere. It is hoped that these calibrated data will be useful to system designers. These calibrated target signature data are not available in the submillimeter wavelength region; nor are data available on optical properties of materials in this submillimeter region. A program is beginning at MICOM which is to fill this gap. It is hoped that the 3.2-mm and 10.6- μm data will aid in interpretation and evaluation of the submillimeter target signature and optical constant parameters.

Figure 1 contains a photograph of the equipment in the upper left corner. The location on the various components is given in the drawing in the upper right. The characteristics of the three subsystems are shown at the bottom of Figure 1. It should be noted that the 10.6- μm system is not diffraction limited nor does it have the same resolution as the 3.2-mm system. The visible data obtained in these experiments only provide coordinate information.

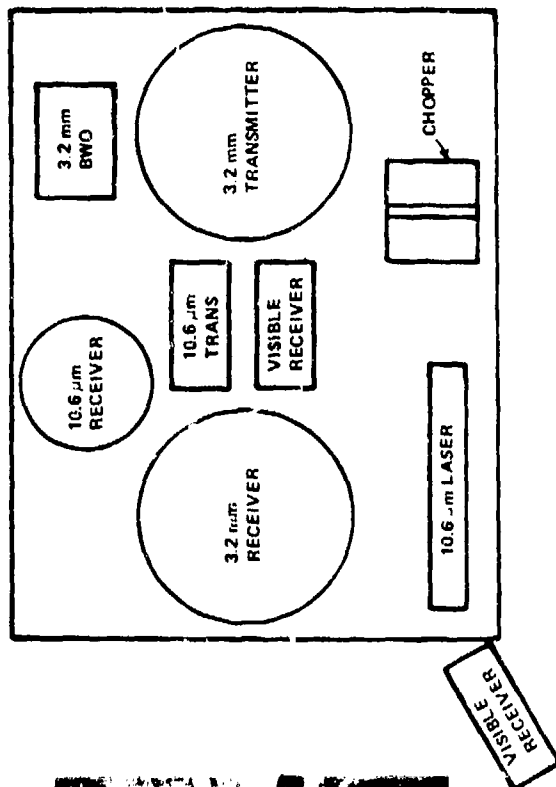
<u>Wavelength</u>	<u>Resolution</u>
3.2 mm	10 cm
10.6 μm	5 cm
Visible	4 cm

Figure 2 shows the targets used in the imaging experiment. The targets are located at the 50-ft range in these photographs.

The actual ranges used in these experiments are displayed in Figure 3. The resolution of the 3.2-mm imaging subsystem is given. The simulated range of a 700- μ m imaging system with a 1-m aperture is given at the bottom of each photograph. Figure 4 contains the image obtained during a run. The analog signal from the sensors modulate the Z-axis of a scope. The scope trace exposed the polaroid film. The middle column contains polaroid photographs of image data displayed on a conographics model C9. The middle photograph on the right is a polaroid photograph taken on-site. The other two photographs in the right-hand column were formed on a high quality, flying spot scanner which was matched to the recording film. The same digital image data were used to produce all of these displays. Figure 5 is another print from the same original used to produce Figure 4. The comparison again emphasizes the effect of the display or reproduction process and the difficulty in providing data for subjective judgement. Figure 6 contains two more aspects of the M48 tank. The 10.6- μ m system has speckle averaging; the 3.2-mm picture does not. The two photographs on Figure 7 are 3.2-mm images taken at 100 ft (a simulated range of 0.7 km). From left-to-right, the objects are a truck, a jeep, and a tank. A corner cube is located between the tank and the jeep. The photograph on the right is a 3.2-mm image taken at 200 ft (a simulated range of 2.1 km). From left to right, the objects are a truck, a tank, and a gasoline fuel storage tank.

Figure 8 contains records of images taken at the various ranges. Because of a parallax problem, no 10.6- μ m images were recorded at 200 and 400 ft. The fuel storage tank is visible in the 200- and 400-ft images. Figure 9 contains records of image data on three different truck types (canvas covered, plywood covered, and open bed) and on two jeep types (canvas covered and open). The top image in each photograph is the 10.6- μ m image; the bottom image is the 3.2-mm image.

SYSTEM

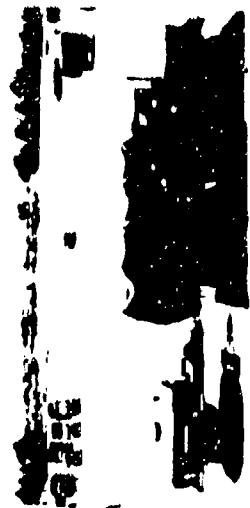


MODE	3.2 mm	10.6 μm	VISIBLE
DETECTION	ACTIVE	ACTIVE	PASSIVE
SOURCE	HETERODYNE	VIDEO	VIDEO
	BACKWARD WAVE OSCILLATOR (BWO)	LASER	
TRANSMITTER APERTURE	45.7 cm	38 mm	
RECEIVER APERTURE	45.7 cm	20 cm	0.02 cm
f NO.	f30	f4	f300

MICOM 6246-1

Figure 1. Hughes mobile image scanner.

TARGETS



CANVAS TRUCK WITH WATER TANK



OPEN TRUCK



MESS TRUCK AND TRAILER
(PLYWOOD SIDES)



JEEPS AND TRAILER



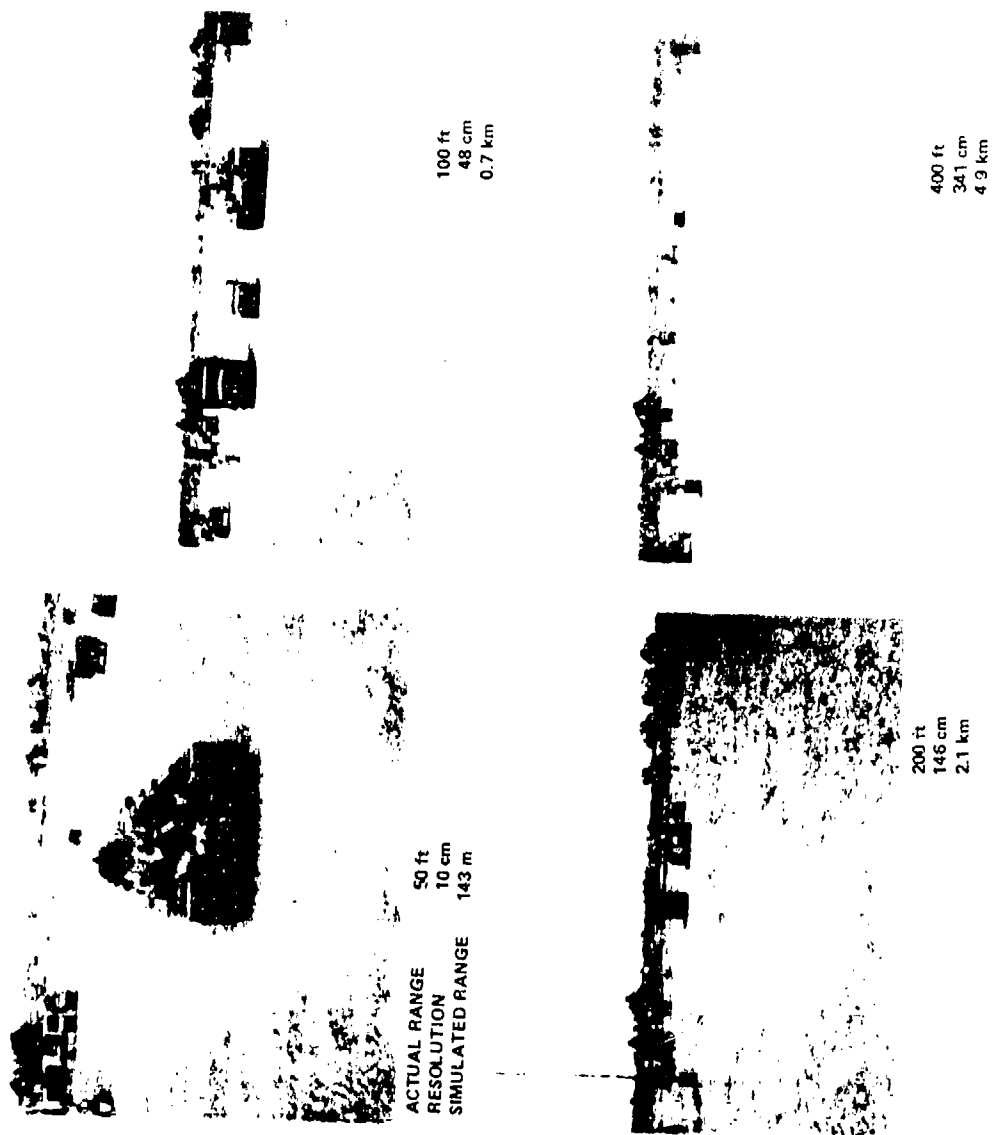
M-48 TANK



PAINT AND METAL SAMPLES

FIG. MICOM 6245-1

Figure 2. Targets.



MICOM 6240-1

Figure 3. Operating ranges.

EFFECTS OF DISPLAY



MICOM 6245-2

Figure 4. Methods of display.

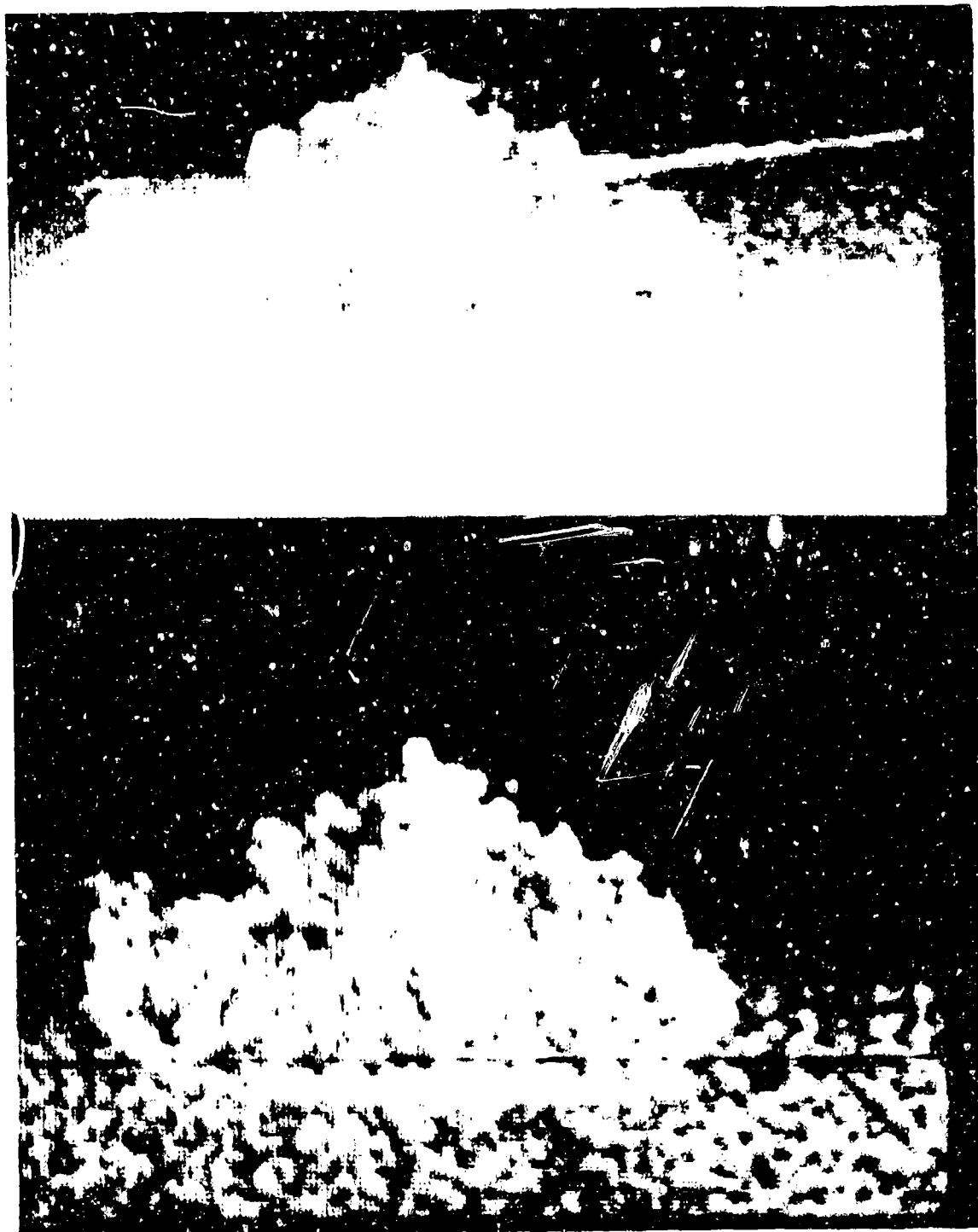


Figure 5. 10.6- μm and 3.2-mm images of a M48A5 tank, side view.

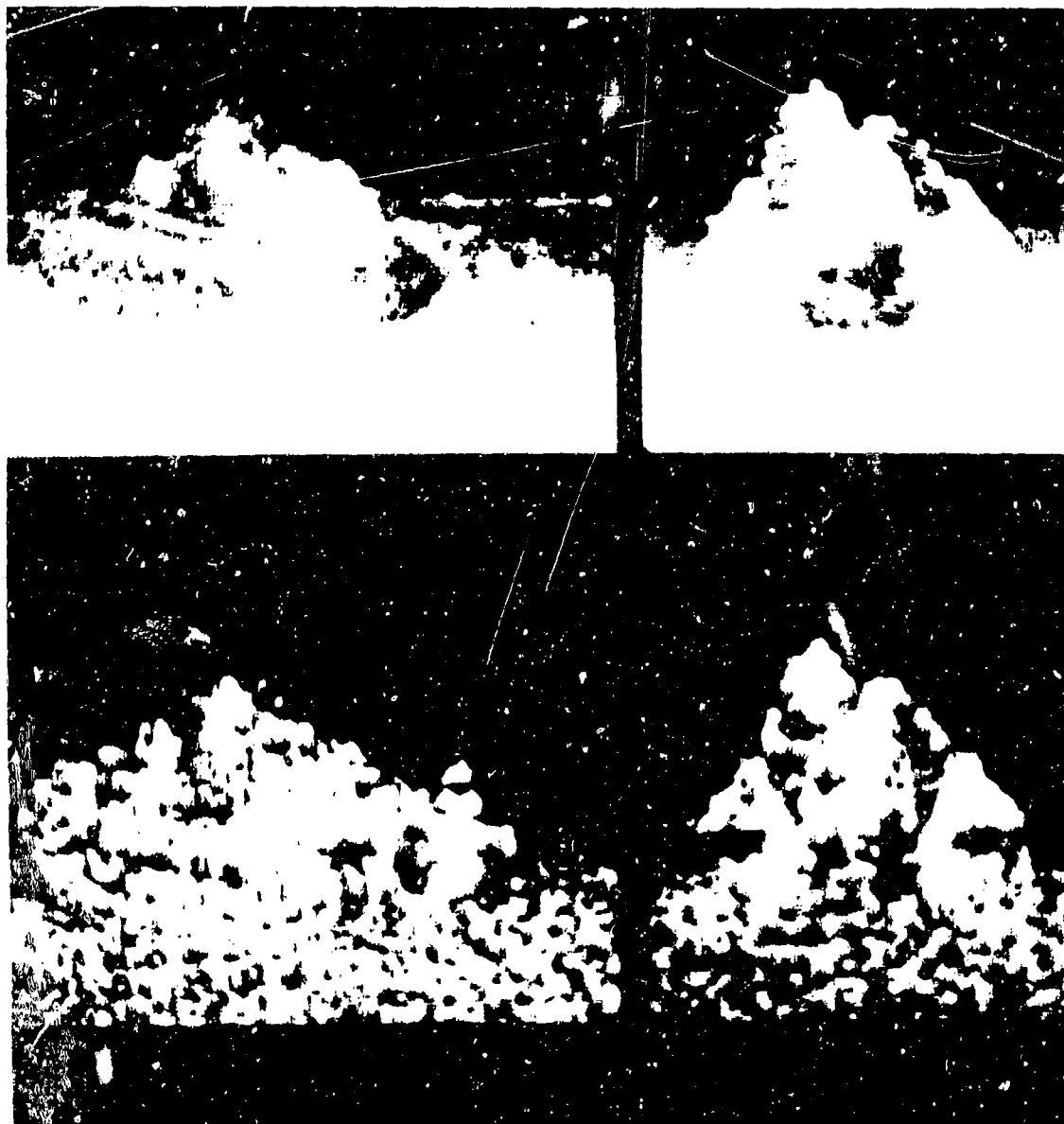


Figure 6. 10.6-mm and 3.2-mm images of a M48A5 tank, 45° and head-on view.

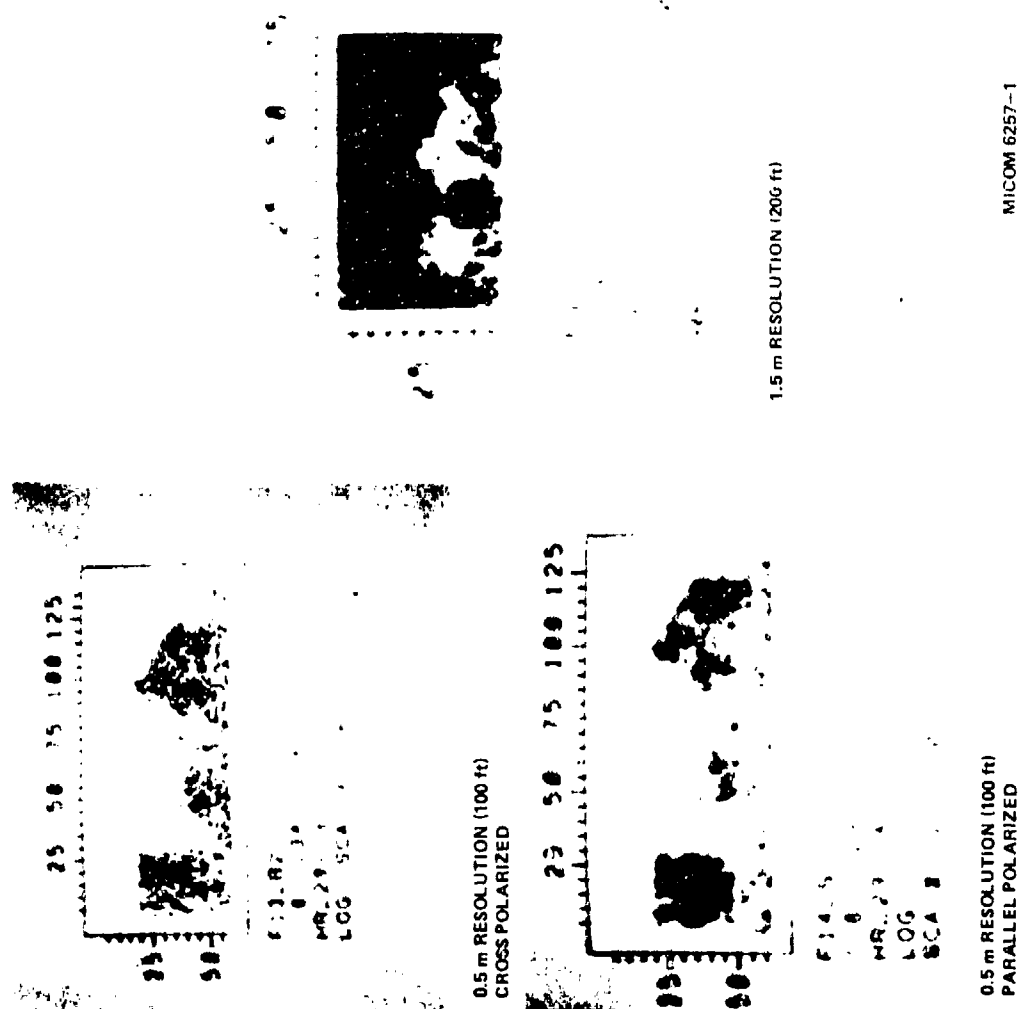


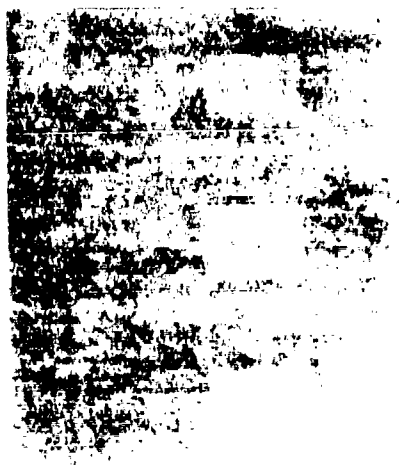
Figure 7. 3.2-mm simulation of 700- μ m images at 0.7-km and 2.1-km ranges.



50 ft



100 ft



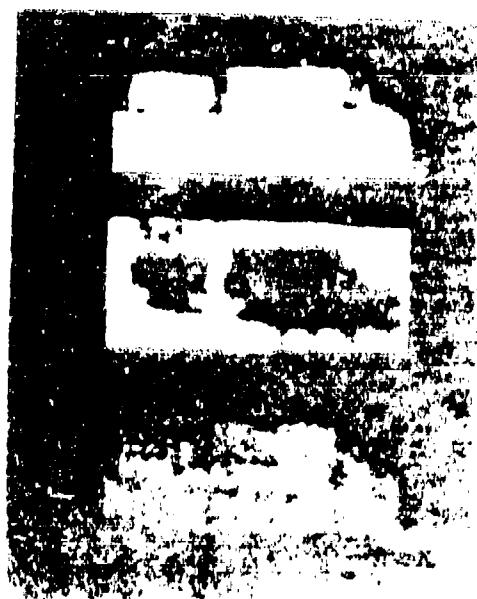
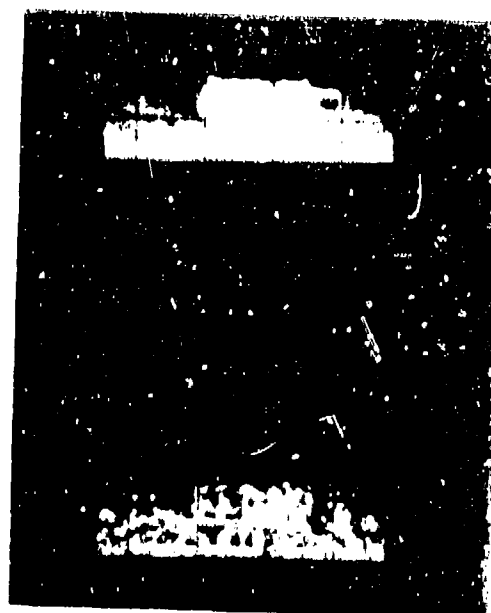
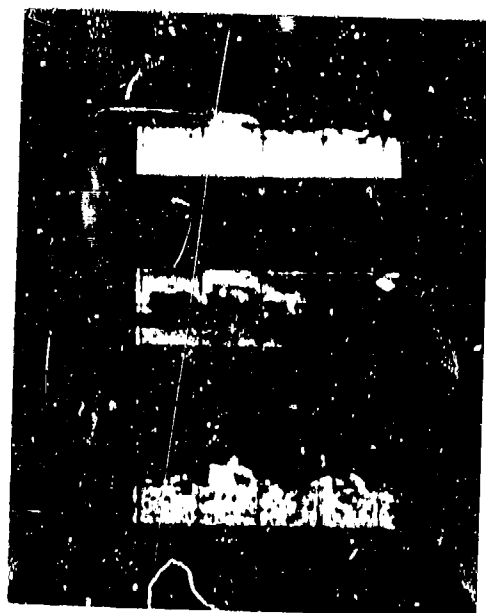
200 ft



400 ft

MICOM 6240-3

Figure 8. Quasi-real-time display at four ranges.



MICOM 6240-2

Figure 9. Quasi-real-time display of trucks and jeeps.

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